The Society of Automotive Engineers Clean Snowmobile Challenge 2002

FINAL REPORT

Lori M. Fussell, Ph.D.
Institute of Science, Ecology, and the Environment
2570 Teton Pines Drive
Wilson, WY 83014
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Institute of
Science,
Ecology, and the
Environment

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EXECUTIVE SUMMARY

In response to increasing concern about snowmobile noise and air pollution, Teton County Wyoming Commissioner Bill Paddleford and environmental engineer Dr. Lori Fussell worked with The Society of Automotive Engineers (SAE) and the Institute of Science, Ecology, and the Environment (ISEE) to organize an intercollegiate design competition, the SAE Clean Snowmobile Challenge (SAE CSC).

The goal of the SAE CSC was to encourage development of a snowmobile with improved emission and noise characteristics that does not sacrifice performance. Modifications were expected to be cost effective and practical.

The third year of the competition, the SAE CSC2002, was held in Jackson Hole, Wyoming from March 23 – 29, 2002. Major sponsors of the SAE CSC2002 included Flagg Ranch Resort, Montana Department of Environmental Quality, Wyoming Department of Environmental Quality, International Snowmobile Manufacturers Association, Teton County Wyoming, United States Department of Energy, and ISEE.

Teams participating in the event competed against each other in the categories of emissions, fuel economy/range, noise, acceleration, handling, cold-start, hill climb, engineering design paper, oral presentation, cost minimization,

and static display. Points were awarded to teams based on their performance in each of the events.

Kettering University and the University of Idaho tied for first place overall at the SAE CSC2002. Kettering University's entry featured a 659cc four-stroke turbocharged engine with electronic fuel injection (closed loop control) and three-way catalytic aftertreatment. The University of Idaho's entry featured a 750cc four-stroke engine with electronic fuel injection (open loop control) and three-way catalytic aftertreatment. Both first-place entries were successful at reducing noise and emissions while simultaneously improving fuel economy and maintaining adequate performance. They were reliable snowmobiles, successfully completing and passing all competition events.

1. INTRODUCTION

Snowmobiles provide hours of exhilarating winter fun for many outdoor enthusiasts, but these fun machines also present an ongoing environmental challenge in the form of excessive exhaust emissions and high noise levels. In an effort to find solutions to the emission and noise challenges presented by snowmobiles, Teton County Wyoming Commissioner Bill Paddleford and environmental engineer Dr. Lori Fussell worked with the SAE to form a new intercollegiate design competition, the Society of Automotive Engineers Clean Snowmobile Challenge (SAE CSC).

By bringing this new competition to engineering students in both the United States and Canada, SAE CSC organizers brought new energy, ideas, and enthusiasm to a much needed environmental/automotive engineering design problem. Students are quickly committed to making their designs succeed and often attempt unique solutions to problems, bringing new perspectives to existing engineering challenges.

Much of the effort behind the formation and organization of the SAE CSC came from within the community of Jackson Hole, Wyoming. A Jackson Hole-based Advisory Board made up of local land managers, businessmen, snowmobilers, and environmentalists assisted the SAE, Commissioner Paddleford, and Dr. Fussell with the development of the competition.

The first SAE CSC (SAE CSC2000) was held in March of 2000. Seven teams from Canada and the United States competed in the first event. A few teams at the competition demonstrated large reductions in snowmobile noise and emissions. However, the majority of the participants suffered from a lack of development time and did not pass the emission and noise tests. (1-7)

The second SAE CSC (SAE CSC2001) was held in March of 2001. Fourteen teams from Canada and the United States competed in the second event. Teams took advantage of the increased development time available for the competition. Over half of the SAE CSC2001 entries passed the emission event and more than one third of the entries passed the noise event. However, reliability was still an issue at the SAE CSC2001, with only one team passing all competition events. (8-16)

The third SAE CSC (SAE CSC2002) was organized jointly by the Society of Automotive Engineers and the Institute of Science, Ecology, and the Environment. It was held in Jackson Hole, Wyoming at the end of March 2002. This report summarizes the results of this event.

Major sponsors of the SAE CSC2002 included Flagg Ranch Resort, Montana Department of Environmental Quality, Wyoming Department of Environmental Quality, International Snowmobile Manufacturers Association, Teton County Wyoming, United States Department of Energy, and The Institute of

Science, Ecology, and the Environment. A complete list of competition sponsors is located at the end of this report.

The goals of the SAE CSC2002 were:

- To give a hands-on, team-oriented, engineering design experience to university students.
- To encourage the research and development of advanced snowmobile technology.
- To give snowmobilers, outfitters, land managers, government officials, and those concerned about the environment the opportunity to work together to help find solutions that will decrease the impact of snowmobiles on the environment.
- To provide positive publicity opportunities for SAE CSC2002 sponsors and the community surrounding Jackson Hole and Teton County Wyoming.

2. COMPETITION OVERVIEW

2.1. Object of Competition

The object of the SAE CSC2002 was to develop a snowmobile that is acceptable for use in environmentally sensitive areas. The modified snowmobiles were expected to be quiet, emit significantly less unburned hydrocarbons (UHC) and carbon monoxide (CO) than conventional snowmobiles, and maintain or improve the performance characteristics of conventional snowmobiles. The modified snowmobiles were also expected to be cost-effective.

Although the modified snowmobiles competed in several performance events, the intent of the competition was to design a touring snowmobile that would primarily be ridden on groomed snowmobile trails. The use of unreliable, expensive solutions was strongly discouraged.

2.2. General Rules

Once selected for participation in the SAE CSC2002, student competitors had just seven months to make modifications to a snowmobile of their choice. Modifications were permitted to the snowmobile's engine, suspension, fuel management system, drivetrain, track, skis, and body. Major modification restrictions included:

- Two-stroke and rotary engines were limited to a displacement of 600 cc, and four-stroke engines were limited to a displacement of 960 cc.

- The snowmobile's chassis and track had to be commercially available.
- Fuel was limited to a blend of 90% premium gasoline and 10% ethanol.
- Fuel additives (with the exception of commercial two-stroke oil) were not permitted.
- The snowmobile had to remain track driven and ski steered.
- The snowmobile had to be propelled with a variable ratio belt transmission.
- Traction control devices were not allowed.

A complete listing of competition rules and restrictions is available in *The SAE Clean Snowmobile Challenge 2002 Rules* (17), located in the Appendix of this report.

2.3. Competition Events and Scoring

Student teams in the SAE CSC2002 competed in six dynamic events and four static events. Dynamic events included emissions, fuel economy/range, noise/acceleration, handling, cold-start, and hill climb. Static events included engineering design paper, oral presentation, technology implementation cost assessment (TICA), and static display.

A total of 1500 points were available in the competition. A breakdown of the points that were available for each event is located in Table 1.

Table 1 *CSC2002 Events and Available Points*

Event	Points Awarded for Passing Event	Additional Points Available for Relative Performance in Event
Emissions	100	350
Fuel Economy/Range	100	100
Combined Noise & Acceleration	100	250 (150-noise, 100 accel.)
Handling	Not Applicable	50
Cold Start	75	Not Applicable
Hill Climb	Not Applicable	75
Cost Assessment	Not Applicable	50
Engineering Design Paper	Not Applicable	100
Oral Presentation	Not Applicable	100
Static Display	Not Applicable	50
Total Points	**375**	**1125**

3. COMPETITION ENTRIES

3.1. Participating Universities

All collegiate chapters of the SAE were invited to submit a proposal to compete in the SAE CSC2002. Seventeen universities from the United States and Canada were selected to participate. The selected universities were:

- Clarkson University
- Colorado School of Mines
- Colorado State University
- Idaho State University
- Kettering University
- Michigan Technological University
- Minnesota State University, Mankato
- Montana State University
- University at Buffalo, State University of New York
- University of Alaska, Fairbanks
- University of Alberta
- University of Idaho
- University of Maine
- University of Waterloo
- University of Wisconsin, Madison
- University of Wisconsin, Platteville
- University of Wyoming

Of the seventeen selected universities, all but two attended and competed in SAE CSC2002 events. Montana State University and the University of Maine withdrew prior to the start of the competition.

3.2. Technical Description of Entries

Essentially, three distinct approaches to meeting competition objectives were used by SAE CSC2002 participants. They were:

1. Use of a conventional two-stroke snowmobile engine with modified fuel management and the addition of exhaust aftertreatment.

2. Use of a conventional two-stroke snowmobile engine modified for direct injection, with catalytic aftertreatment.

3. Use of a four-stroke engine (automotive, motorcycle, and all terrain vehicle engines were all used) featuring electronic fuel injection and the addition of exhaust aftertreatment. Half of the four-stroke entries were turbocharged.

Detailed information on the teams' design strategies, challenges faced, and final results are available in the individual SAE CSC2002 participants' engineering design papers (18-26). A summary of all SAE CSC2002 snowmobiles is included in Table 2.

Table 2 *Summary of SAE CSC2002 Modification Strategies*

Participant	Base Chassis	Base Engine	Engine Cycle	Engine Management	Fuel Delivery	Emission Control Strategy	Noise Control Strategy
Clarkson University	1999 Arctic Cat SnoPro	Honda CBRT 929RR 929cc (Motorcycle)	4-stroke	Stock	Electronic Fuel Injection (EFI)	Three way catalyst (TWC)	Insulated engine compartment, Muffler
Colorado School of Mines	1993 Arctic Cat Mountain Cat EXT	Suzuki 550 cc (Snowmobile)	2-stroke	Stock	EFI	Oxidation catalyst (OXC)	Dynamat, expansion chamber
Colorado State University	Arctic Cat ZRT 600	Arctic Cat 594 cc (Snowmobile)	2-stroke	Orbital	Direct Injection	Direct injection, Lean operation with two OXCs	Sound dampening foam, modified air box, quarter wave resonators on exhaust
Idaho State University	Polaris RMK	Polaris 500 cc (Snowmobile)	2-stroke	Heltech	EFI	TWC	Header wrap, sound absorbing material
Kettering University	2000 Yamaha V-max 600 Deluxe	Turbocharged 659cc Daihatsu (Automobile)	4-stroke	Stock	EFI	Closed loop operation with TWC	Custom exhaust, tunnel dampening coating, multiple wheel kits, custom skirting for tunnel noise
Michigan Technological University	1999 Arctic Cat SnoPro	Turbocharged Polaris 500cc (All Terrain Vehicle)	4-stroke	Hymark	EFI	Stoichiometric operation with three way catalyst	Team designed intake and exhaust systems, sound dampening material, team designed driveline
Minnesota State University, Mankato	2000 Polaris Edge	Turbocharbed Polaris 500 cc (All Terrain Vehicle)	4-stroke	Motec M48	EFI	TWC	Custom exhaust system utilizing frequency cancellation, sound absorbing materials
University at Buffalo, State University of New York	1999 Yamaha Vmax 500 SX	Turbocharged Polaris 500cc (All Terrain Vehicle)	4-stroke	Magneti Marelli	EFI	Closed loop operation with TWC and OXC	Melamene foam
University of Alaska, Fairbanks	1998 Arctic Cat Powder Extreme	Turbocharged Suzuki 954 cc (Automobile)	4-stroke	Nippendenso/ Bosch	EFI	Closed loop operation with TWC and EGR, Positive crankcase ventilation	Two stage auto muffler, sound insulation
University of Alberta	2000 SkiDoo MXZX 440	Suzuki GSXR 600cc (Motorcycle)	4-stroke	Haltech	EFI	Closed loop operation with TWC	Dual-expansion chamber muffler, absorption pre muffler
University of Idaho	2001 Arctic Cat SnoPro	BMW K75RT 750cc (Motorcycle)	4-stroke	Open loop ECU	EFI	Open loop operation with TWC	Under-hood sound damping
University of Waterloo	2001 Ski Doo MXZ 600	Rotax 600 cc (Snowmobile)	2-stroke	Mechanical	Carburetors	Dual bed TWC with secondary air injection	Muffler under seat
University of Wisconsin, Madison	2001 Polaris XC Edge 800 XP	Kawasaki 900 cc (Motorcycle)	4-stroke	Mototron	EFI	Closed loop operation with TWC	Resonator, muffler, 4 foot rear exhaust
University of Wisconsin, Platteville	1995 Ski Doo Formula III	Ski Doo 600 cc (Snowmobile)	2-stroke	Stock	Carburetors	Lean operation with TWC	Composite sound abatement material, stock silencer, internal stingers in pipes
University of Wyoming	1996 Polaris XLT	Polaris 600cc (Snowmobile)	2-stroke	Stock	Carburetors	Rich operation with TWC	Muffler, sound deadening foam

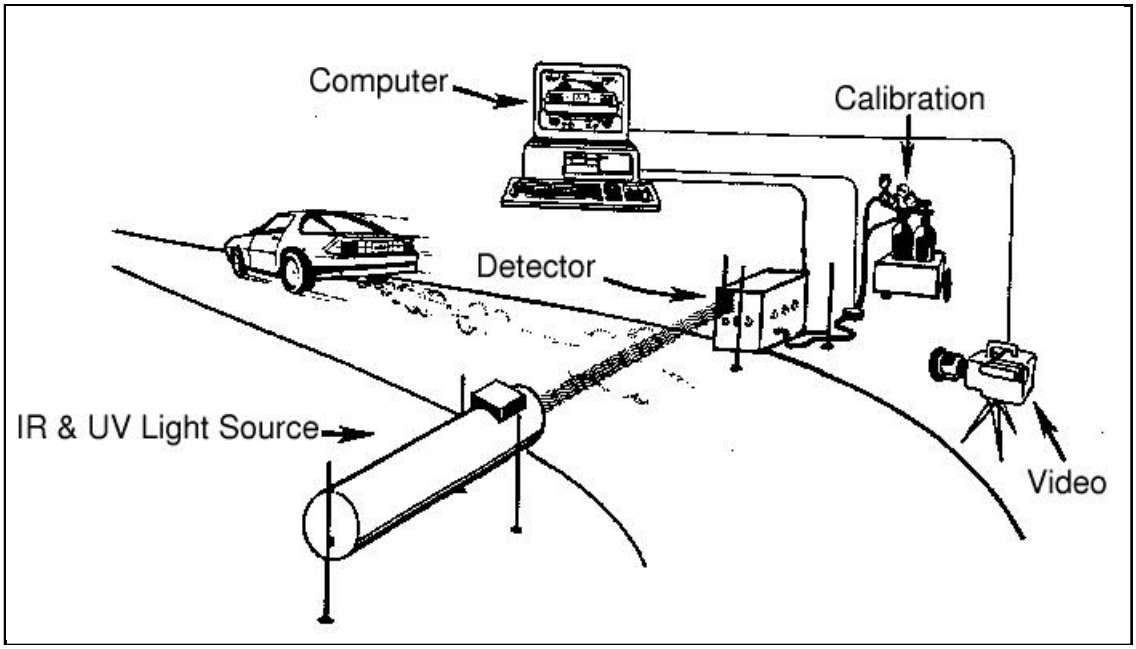
4. EVENT DESCRIPTIONS AND RESULTS

4.1. Emission Test

Carbon monoxide (CO) and unburned hydrocarbon (UHC) emissions were measured from all SAE CSC2002 snowmobiles. Emission measurements were taken utilizing the Fuel Efficiency Automobile Test (FEAT) equipment developed at the University of Denver.

The FEAT is an infrared (IR) and ultraviolet (UV) remote monitoring system for vehicle CO, UHC, and NO exhaust emissions (27). Figure 1 shows a schematic diagram of the instrument.

Figure 1 *Schematic Diagram of the FEAT*



The instrument and techniques employed have been fully described in the literature and only a brief overview will be provided here (28,29). The FEAT instrument was designed to emulate the results one would obtain using a conventional non-dispersive infrared (NDIR) exhaust gas analyzer. Thus, FEAT is also based on NDIR principles. An IR source sends a horizontal beam of radiation across a single traffic lane, approximately 10 inches above the road surface. This beam is directed into the detector on the opposite side and divided between four individual detectors: CO, carbon dioxide, UHC, and reference. An optical filter that transmits infrared light of a wavelength known to be uniquely absorbed by the molecule of interest is placed in front of each detector, determining its specificity. Reduction in the signal caused by absorption of light by the molecules of interest reduces the voltage output. One way of conceptualizing the instrument is to imagine a typical garage-type NDIR instrument in which the separation of the IR source and detector is increased from 8 centimeters to 6-12 meters. Instead of pumping exhaust gas through a flow cell, a car now drives between the source and the detector.

The FEAT has been shown to give accurate readings for CO and UHC in double-blind studies of vehicles both on the road and on dynamometers (30-32). Ashbaugh et al. (33) used a fully instrumented vehicle with tailpipe emissions

controllable by the driver/passenger in a series of drive-by experiments with the vehicles emissions set for CO between 0-10% and between 0-0.35% (propane) for UHC to confirm the accuracy of the on-road readings. The results are an accuracy of ñ5% for CO and ñ15% for UHC. Recently, the abilities to measure nitric oxide and exhaust opacity have been added (34).

The FEAT has been easily adapted for measurements of snowmobile exhaust emissions and has been successfully used to make two in-use surveys of snowmobile emissions in Yellowstone National Park in the winter of 1998 and 1999 (35, 36). It was also used to measure snowmobile emissions at the SAE CSC2000 (1). The FEAT source and detector were placed on insulating pads on top of the snow. Snowmobile exhaust exits at the front of the sleds toward the ground, so the beam height was lowered to approximately 15 cm (6 in) above the snow. Sampling time was extended from 1/2 second for cars to a full second for snowmobiles. This allows additional time for the rear of the sled to clear the beam. To reduce snow spray a plastic artificial snow matte, approximately 1.2 m x 2.4 m (4 ft x 8 ft) in size, was laid on top of the snow directly under the path of the sensing beam. The video camera photographed the front cowling of each sled as it was measured for a permanent video record of the event. The support equipment was housed nearby in the University's mobile home. The instrument was calibrated before and after each measurement period using a certified gas cylinder

(Praxair, Danbary, CT.). Temperature, humidity and pressure were recorded for all of the measurement sessions.

In the SAE CSC2002, the FEAT was used to measure CO and UHC emissions during two different modes of operation:

1. A gentle acceleration from 0 to 24 km/h (15 mph), to simulate a snowmobile pulling away from an entrance gate.

2. A climb up a hill (7.7 percent grade) at a constant speed of 32 km/h (20 mph).

Testing took place at an altitude of approximately 2,260 meters (7,400 feet) above sea level. Temperatures ranged from –3 to 3°C (27 to 37 °F). Wind speed was less than 1 meter/second. Trail conditions were 1" of fresh snow on a 48" base.

Professional drivers drove the snowmobiles during the emission tests. A radar gun was used to verify correct snowmobile speed.

Ten measurements of each mode were taken for each snowmobile. The highest and lowest measurements for each mode were thrown out. The remaining sixteen measurements were averaged together to generate each snowmobile's average CO and UHC emission in parts per million (ppm).

SAE CSC2002 participants were expected to reduce the CO and UHC emissions by at least 50% (relative to the control snowmobile) to pass the event.

Teams received 100 points for passing emissions, with another 350 points available to teams based upon their ability to reduce emissions beyond competition minimums. Emission reductions were calculated based on the emissions of a 2001 Polaris Sport Touring snowmobile equipped with a 550 cc 2-stroke engine. Test results are summarized in Table 3.

Colorado State University (CSU) won the emissions event with its direct injected two-stroke entry. As indicated in Table 3, the CSU team reduced UHC by 88.6% and CO by 99.4%.

Five other entries in the SAE CSC2002 also achieved significant reductions in emissions. These teams reduced both CO and UHC emissions by more than 50%. Four of these snowmobiles featured a four-stroke engine and one of these snowmobiles featured a two-stroke engine.

Five of the SAE CSC2002 entries that failed the emission test achieved a greater than 88% reduction in UHC while *increasing* CO emissions anywhere from 7% to 43%. Essentially, there was not enough oxygen present in the exhaust of these snowmobiles for the catalyst to completely oxidize both the UHC and CO. Therefore, these teams ended up producing CO in their catalysts. This illustrates the importance of proper engine tuning when using catalysts as an emission control strategy.

Table 3 *SAE CSC2002 Emission Testing Results*

Participant	CO (ppm)	CO (% Reduction)	UHC (ppm Propane)	UHC (% Reduction)	Points
Clarkson University	77,500	-15.7%*	1,100	90.7%	0
Colorado School of Mines	96,000	-43.4%	8,160	31.3%	0
Colorado State University	400	99.4%	1,360	88.6%	401
Idaho State University	77,000	-14.9%	730	93.9%	0
Kettering University	18,400	72.5%	360	96.9%	332
Michigan Technological University	51,900	22.5%	-100**	>99.5%	0
Minnesota State University, Mankato	95,500	-42.4%	290	97.6%	0
University at Buffalo, State University of New York	25,400	62.1%	210	98.2%	311
University of Alaska, Fairbanks	51,000	23.8%	580	95.1%	0
University of Alberta	28,000	58.2%	710	94.1%	278
University of Idaho	12,700	81.0%	40	>99.5	383
University of Waterloo	27,500	59.0%	2,790	76.5%	208
University of Wisconsin, Madison	Not Tested	Not Tested	Not Tested	Not Tested	0
University of Wisconsin, Platteville	73,700	-10%	1,390	88.3%	0
University of Wyoming	72,200	-7.8	560	95.3%	0
Control Snowmobile	67,000	N/A	11,800	N/A	N/A

** Negative % reductions indicate that the team produced more of the pollutant than the control snowmobile.*

*** The negative hydrocarbon value indicates that Michigan Technological University's hydrocarbons are below the limit of detectability of this test procedure (approximately 100 ppm propane).*

4.2. Fuel Economy/Range Test

All SAE CSC2002 snowmobiles attempted to complete a 93.8 mile trip in Yellowstone National Park. Participants were required to maintain a speed equal to the legal speed limit, which varied from 35 to 45 miles per hour. The required speed was occasionally reduced for safety in poor driving conditions.

Trail conditions were four inches of wet snow on top of a hard pack of groomed snow. The temperature during testing varied from –2 to 4°C (28-39°F).

Snowmobiles began the trip will full tanks. The amount of fuel required to fill the tank upon return was used to award points for this event.

Teams received 100 points for completing the event. An additional 100 points were available based upon teams' fuel economy improvement. Individual team results for the fuel economy/range event are listed Table 4.

Of the fourteen snowmobiles that began the fuel economy/range test, only four snowmobiles finished. The University of Idaho had the best fuel economy at the SAE CSC2002. This entry increased fuel economy to 18.3 mpg from the control snowmobile's 11.7 mpg fuel economy, a 56% improvement.

4.3. Noise/Acceleration Test

All SAE CSC2002 snowmobiles were subjected to noise measurements intended to determine the maximum exterior sound level possible from the

Table 4 *Summary of Event Results and Points Awarded to Teams in the SAE CSC2002*

Participant	CO %Red	UHC %Red	Fuel Economy (MPG)	Max Sound (dBA)	Avg. Accel. (sec)	% Hill Climbed	Time to top (sec)	TITC ($)	Handling Points	Cold Start Points	Eng. Design Paper Points	Oral Design Pres. Points	Static Display Points	Penalty Points	Weight with full fuel (lb)	ORDER OF FINISH
	Emission Points		Fuel Economy Points	Noise & Acceleration Points		Hill Climb Points		TITC Points								Final Score
Clarkson University	-15.7%	90.7%	Did Not Finish (DNF)	75	7.95	26%	NA	$943.58	33.5	75.0	68.0	65.3	35.8	0.0	642	9th
	0.0		0.0	0.0		3.4		27.6								309
Colorado School of Mines	-43.4%	31.3%	DNF	78	12.62	0%	NA	$773.25	0.0	75.0	64.5	42.7	30.3	0.0	648	12th
	0.0		0.0	0.0		0.0		47.8								260
Colorado State University	99.4%	88.6%	DNF	75	9.76	20%	NA	$1,002.26	35.1	75.0	93.3	84.2	42.4	-25.0	731	3rd
	401.0		0.0	0.0		2.0		22.9								731
Idaho State University	-14.9%	93.9%	DNF	75	9.72	1%	NA	$797.20	21.9	75.0	64.0	30.2	29.8	0.0	666	11th
	0.0		0.0	0.0		0.0		44.2								265
Kettering University	72.5%	96.9%	14.6	71	9.01	22%	NA	$817.77	32.2	75.0	71.6	80.4	39.3	0.0	720	1st (TIE)
	332.0		144.7	350.0		2.4		41.3								1169
Michigan Technological University	22.5%	>99.5%	DNF	75	11.12	52%	NA	$1,296.20	17.1	75.0	76.8	80.1	34.4	-25	614	10th
	0.0		0.0	0.0		13.5		8.1								280
Minnesota State University, Mankato	-42.4%	97.6%	DNF	DNF	DNF	45%	NA	$1,356.50	0.0	0.0	83.3	66.5	37.3	-100	683	15th
	0.0		0.0	0.0		10.1		6.2								103
University at Buffalo, SUNY	62.1%	98.2%	DNF	68	11.70	77%	NA	$1,580.7	29.7	75.0	70.7	70.2	41.4	-25	641	4th
	311.0		0.0	0.0		29.6		0.9								604
University of Alaska, Fairbanks	23.8%	95.1%	DNF	75	8.90	45%	NA	$1,634.10	24.5	75.0	76.0	64.6	35.8	-95.0	754	13th
	0.0		0.0	0.0		10.1		0.0								191
University of Alberta	58.2%	94.1%	DNF	79	9.58	25%	NA	$1,057.50	35.6	0.0	79.0	62.5	39.3	-10.0	684	5th
	278.0		0.0	0.0		3.1		19.1								507
University of Idaho	81.0%	>99.5%	18.3	73	9.41	81%	NA	$903.75	38.1	75.0	82.8	69.8	42.3	0.0	670	1st (TIE)
	383.0		200.0	216.3		32.8		31.3								1171
University of Waterloo	59.0%	76.5%	DNF	75	10.82	30%	NA	$871.50	33.0	0.0	74.0	62.0	38.1	-25.0	613	8th
	208.0		0.0	0.0		4.5		34.7								429
University of Wisconsin, Madison	DNF	DNF	DNF	80	8.38	82%	NA	$1022.00	42.1	0.0	64.2	62.2	38.8	-125.0	Not weighed	14th
	0.0		0.0	0.0		33.6		21.5								137
University of Wisconsin, Platteville	-10%	88.3%	11.2	78	7.54	100%	53.557	$1,121.50	43.3	75.0	59.6	48.8	30.9	0.0	657	7th
	0.0		103.3	0.0		75.0		15.5								451
University of Wyoming	-7.8%	95.3%	10.8	78	7.28	100%	54.533	$759.88	50.0	75.0	71.0	64.1	39.3	0.0	551	6th
	0.0		100.0	0.0		50.0		50.0								499
Control Snowmobile	NA	NA	11.7	80	8.60	NA	NA	NA	NA	NA	NA	NA	NA	NA	Not weighed	NA
	NA		NA	NA		NA		NA								NA

competing snowmobiles. The noise level measurements were taken in conjunction with the acceleration event. This ensured that snowmobiles were operating at wide-open throttle during noise testing.

Noise measurements were taken in accordance with a modified version of SAE J192 (37), the SAE recommended practice for measuring the exterior sound level from snowmobiles. This test procedure measures snowmobile noise while under wide open throttle acceleration, with measuring equipment located 50 ft from the road. Measurements are taken on both sides of the snowmobile. The modifications to SAE J192 used at the SAE CSC2002 were a slow response setting on the meter and an acceleration distance of 250 feet.

Tests were run until three readings within a 2 dBA range per snowmobile side were obtained. The sound level recorded for each side of the snowmobile was recorded as the average of all three readings, rounded to the nearest integer. The sound level used for scoring purposes was that for the side of the snowmobile with the highest reading.

For the acceleration test, snowmobiles were evaluated on the basis of elapsed time to 500 feet from a standing start. Teams were scored based on the average of the three acceleration times for which valid noise measurements were obtained.

The instruments used for the noise testing were a Quest Technologies 2400, #JN9070047 and a Quest Technologies 2100, #DAA070020. The instruments were allowed to equilibrate to ambient temperature for the hour it took to set up the test track. The instruments were calibrated, with appropriate corrections made for ambient conditions.

The noise measurement instruments were oriented horizontally, with the microphone set 1.5 m (60 inches) above the hard snow surface. A windscreen was in place. Background noise was between 40 to 55 dBA.

JACircuits timing equipment was set up measure the elapsed time from 0 to 500 feet for the acceleration portion of this event. This equipment measures elapsed time between two points using a pulsed infrared light beam at the start and finish line. However, blowing snow during testing interfered with the JACircuits timing equipment. Therefore, acceleration times were measured manually, under the supervision of the Sports Car Club of America.

The test track was set up near the Cathedral Group turnout in Grand Teton National Park. The snow surrounding the track was approximately three feet deep of hard packed snow. The elevation of the test site was 1920 meters (6295 feet) above sea level. The temperature during testing was in the mid 20s (°F). Wind speed averaged 9 miles/hour with an occasional 21 mile/hour gust. Due to the gusting winds, tests were occasionally delayed until background noise dropped

below 55 dBA. No measurements were taken when the background noise was greater than 55 dBA.

All snowmobiles in the SAE CSC2002 were expected to complete this event with an average acceleration time equal to or less than 10.5 seconds and a maximum exterior sound level equal to or less than 74 dBA. Snowmobiles that did not meet either of these criteria failed the combined event and received 0 points. Snowmobiles that met these criteria received 100 points, with an additional 250 points available based upon their relative improvement. Results are presented in Table 4.

The University of Kettering won the noise/acceleration event, reducing the maximum sound level to 71 dBA while accelerating from 0 to 500 feet in 9.011 seconds. The control snowmobile measured 80 dBA, with an average acceleration time of 8.601 seconds.

The University of Idaho was the only other SAE CSC2002 entry that passed the combined noise/acceleration event. This snowmobile measured 73 dBA, with a corresponding average acceleration of 9.413 seconds.

Five of the teams that failed the combined noise/acceleration event achieved acceptable acceleration but were 1 dBA shy of meeting the competition's stringent noise standard of 74 dBA. The University at Buffalo's snowmobile achieved

particularly impressive reductions in noise levels (68 dBA). However, this entry failed the acceleration portion of the event with an average time of 11.697 seconds.

4.4. Hill Climb Event

All participants in the SAE CSC2002 were required to compete in the World Championship Snowmobile Hill Climb. The hill climb event was scored based on maximum height reached or elapsed time to reach the top of a course up Snow King Mountain. The course was approximately 3000 feet long, had an average grade of 19 degrees (39%), and a maximum grade of 30 degrees (60%). Professional snowmobile drivers rode the snowmobiles in this event.

A maximum of 75 points was available in this event. Individual team results and the points awarded for this event are listed in Table 4.

4.5. Technology Implementation Cost Assessment

As part of the SAE CSC2002, each team was required to submit a technology implementation cost assessment (TICA) on their modified snowmobile. The TICA's purpose was to provide a standard method to compare the "manufacturer's cost" (cost to the end snowmobile manufacturer) of each team's strategy for reducing emissions, noise, and fuel consumption. The TICA was not intended to evaluate the manufacturer's cost of "secondary" modifications such as suspension modifications or more comfortable seats.

A maximum of 50 points was available for the Technology Implementation Cost Assessment Event. Final Technology Implementation Total Costs (TITC's) and the points awarded for this event are listed in Table 4.

4.6. Handling Event

The handling capabilities of each modified snowmobile were evaluated by professional snow cross drivers. Drivers based their evaluation on the snowmobiles' cornering, ride, engine response, braking, clutching, and overall performance.

A maximum of 50 points was available for the handling event. Individual team results for the handling event are listed in Table 4.

4.7. Cold Start Event

Because cold starting is essential in a snowmobile, the SAE CSC2002 cold start event was a pass/fail event. SAE CS2002 snowmobiles were cold-soaked overnight. Teams had exactly twenty seconds to start their snowmobile. Snowmobiles that started within 20 seconds passed the cold start event and received 75 points. Cold start testing took place at 3 °C (38 °F).

Individual team results for the cold start event are listed in Table 4.

4.8. Engineering Design Paper

This event required SAE CSC2002 teams to write an engineering design paper describing their snowmobile modifications. Students were expected to

explain why modifications were performed and document the results of their snowmobile development and testing. Students were also expected to include a detailed cost analysis of their modifications (including justification for any increased cost of the snowmobile). Finally, teams were expected to address the durability and practicality of any modifications.

SAE CSC2002 engineering design papers were judged on content, organization, use of graphics, and references.

A maximum of 100 points was available for the engineering design paper event. Individual team results for the engineering design paper event are listed in Table 4.

4.9. Oral Presentation

Each SAE CSC2002 team made a ten-minute oral presentation on the rationale and approach to their snowmobile modifications. A five-minute question and answer period followed each presentation.

In their presentation, teams were expected to clearly state how their modified snowmobile addresses the needs of snowmobilers (performance), land managers and those concerned about the environment (noise and emissions), and snowmobile tour operators (cost, durability/re-sale value).

SAE CSC2002 oral presentations were judged on content, format, delivery, effectiveness of visual aids, and ability to answer judges' questions. A maximum

of 100 points was available for the oral presentation event. Individual team results for the oral presentation event are listed in Table 4.

4.10. Static Display

As part of the SAE CSC2002, each team placed their snowmobile on display at the World Championship Hill Climb, held March 29th through April 1st in Jackson Hole, Wyoming. Static displays were expected to encourage visitors to purchase the prototype snowmobiles and educate visitors about the need to reduce noise and emissions from snowmobiles. Teams were encouraged to put up signs, hand out flyers, and use any other marketing techniques to attract attention to their prototype snowmobile.

SAE CSC2002 static displays were judged on aesthetics, student knowledge, handouts/posters, and overall impression. A maximum of 50 points was available for the static display event. Individual team results for the static display event are listed in Table 4.

4.11. Snowmobile Weights

All competition snowmobiles were weighed at the SAE CSC2002. Snowmobiles were weighed with full fuel. The weights were not used for scoring, but were collected for informational purposes only. These weights are provided in Table 4.

4.12. Penalties Assessed During the CSC2002

SAE CSC2002 participants received penalty points for arriving late at the competition, submitting their engineering design paper late, performing unscheduled maintenance on their snowmobile, and/or violating competition safety rules. The penalty points assessed during the SAE CSC2002 are summarized below:

- Colorado State University, -25 points for unscheduled maintenance
- Michigan Technological University, -25 points for unscheduled maintenance
- University of Waterloo, -25 points for unscheduled maintenance
- Minnesota State University Mankato, -100 points for unscheduled maintenance
- University at Buffalo State University of New York, -25 points for unscheduled maintenance
- University of Alberta, -10 points for late paper
- University of Alaska Fairbanks, -20 points for late paper and –75 points for unscheduled maintenance
- University of Wisconsin Madison, -125 points for unscheduled maintenance

4.13. Summary of Competition Winners

The points awarded to each team in the competition and their final standings are summarized in Table 4. In addition to awards for final overall standing, several category awards were presented to SAE CSC2002 competitors. They are listed below.

- *Best Emissions:* Colorado State University
- *Best Fuel Economy:* University of Idaho
- *Quietest Snowmobile:* Kettering University
- *Best Design:* University of Idaho[1]
- *Best Performance:* University of Idaho[1]
- *Best Value:* Kettering University[2]
- *Most Practical:* Kettering University[3]
- *Hill Climb Champion:* University of Idaho[1]
- *Most Sportsmanlike:* Minnesota Sate University, Mankato

[1] Teams were required to pass noise and emissions to be eligible to receive this award.
[2] The award for Best Value was awarded to the team with the best balance between cost, fuel economy, and performance.
[3] The award for Most Practical was presented to the team with the best balance between cost, noise reduction, and emission reduction.

5. CONCLUSION

The University of Idaho and Kettering University shared the first place award at the SAE CSC2002. At the end of the competition, just two points separated these top finishers and competition organizers declared the event a tie. The two winning entries earned the distinction of being the only snowmobiles in the competition to complete and pass every event and established at least temporary superiority for the four-stroke engine as the most effective design strategy for cleaner, quieter snowmobiles.

The first-place entry from the University of Idaho featured a BMW 750 cc four-stroke motorcycle-powered Arctic Cat with electronic fuel injection and a catalyst. This clean and quiet sled demonstrated a 56% improvement over the control sled in fuel economy.

The first-place entry from Kettering University featured a 659 cc Daihatsu turbocharged, electronically fuel injected four-stroke engine pulled from a Daihatsu Mira micro van sold in Japan. This entry was the quietest among those showing good acceleration results, just 71 dBA, 50 feet from the road at full throttle.

The third-place entry from Colorado State University (CSU) achieved impressive emission results with a direct injected two-stroke engine. It reduced CO emissions by 99.4% and UHC emissions by 88.6% compared to the control

snowmobile. The CSU entry was 1 dBA shy of passing competition noise standards and ran into trouble during the fuel economy/range test. However, it's impressive emission reductions show that direct injection two-stroke engines have potential as a method to significantly reduce emissions from snowmobiles.

With six SAE CSC2002 teams passing the competition's strict emission standard and just two SAE CSC2002 teams passing the competition's combined noise/acceleration standard, it appears that the focus of successful participants in future competitions will be on tackling the noise/acceleration challenges of a cleaner snowmobile.

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APPENDIX

The SAE Clean Snowmobile Challenge 2002 Rules

The SAE Clean Snowmobile Challenge 2002 Rules
Revised January 2002

Administered by:
The Society of Automotive Engineers
and
The Institute of Science, Ecology, and the Environment

1. BACKGROUND

1.1 Introduction

The Society of Automotive Engineers Clean Snowmobile Challenge 2002 (SAE CSC2002) is an engineering design competition for college and university student members of the Society of Automotive Engineers (SAE), organized and administered by the SAE and the Institute of Science, Ecology, and the Environment (ISEE). Competition organizers will allow up to twenty teams to compete in the SAE CSC2002. Selection for competition in the SAE CSC2002 will be given to schools submitting the best proposals for re-designing a snowmobile to improve its emissions and noise while maintaining its performance characteristics. The modified snowmobiles will compete in Jackson, Wyoming beginning on March 23, 2002 in a variety of events including emissions, noise, fuel economy/range, acceleration, power, and design. Prize money totaling $21,000 will be awarded at the end of the competition on March 29, 2002.

1.2 Competition Objective

The intent of the competition is to develop a snowmobile that is acceptable for use in environmentally sensitive areas. The modified snowmobiles are expected to be quiet, emit significantly less unburned hydrocarbons and carbon monoxide than conventional snowmobiles (without significantly increasing oxides of nitrogen emissions), and maintain or improve the performance characteristics of conventional snowmobiles. The modified snowmobiles are also expected to be cost-effective. Although the snowmobiles will compete in both a hill climb event and a handling event, the intent of the competition is to design a touring snowmobile that will primarily be ridden on groomed snowmobile trails. The use of unreliable, expensive solutions is strongly discouraged!

2. ELIGIBILITY

2.1 University Eligibility

Engineering proposals will be accepted from student teams at accredited colleges and universities. High school teams will not be permitted to participate.

2.2 Team Member Eligibility

Undergraduate participation is strongly encouraged. Graduate student participation is allowed, but limited to no more than 25% of the undergraduate participation on any individual team.

2.3 University Collaboration

Collaboration between schools will be accepted if both schools meet all requirements stated in these rules.

2.4 Required Engineering Proposal

A college or university team wishing to participate in the SAE CSC2002 must submit an engineering proposal covering the conversion of a snowmobile.

2.5 Participant Selection

A review panel will select up to twenty (20) teams to participate in the SAE CSC2002 based on the quality of their engineering proposal.

2.6 SAE CSC2002 Permitted Participants

Only teams selected by the review panel may participate in the SAE CSC2002. Teams not selected by the review panel may not participate in the SAE CSC2002.

2.7 SAE Membership/Driver's License

All participants must be student members of the Society of Automotive Engineers (SAE) with a valid membership card. Applications for membership will not suffice. All snowmobile drivers must have a valid driver's license.

2.8 Medical Insurance

All snowmobile drivers must present proof of medical insurance coverage that is valid in the United States.

3. ENGINEERING PROPOSAL REQUIREMENTS

3.1 Engineering Proposal Format

Proposals must be no more than two pages (one-sided) in length and must contain the following information:

- University/College
- Faculty Advisor and Contact Information
- Student Team Leader and Contact Information
- Number of students already "signed-up"
- Brief Description of Approach to Reduce Noise and Emissions, including specification of engine and exhaust aftertreatment (if any)
- Brief Description of Approach to Power Retention
- Brief Description of Project Timeline
- Evidence of Adequate Funding for the Project
- Evidence of Adequate Facilities for the Project

3.2 School Support

Proposals must be submitted with a cover letter signed by the dean of the school of engineering (or the equivalent) expressing the school's support and approval of the entry. Failure to include this letter will disqualify the proposal from consideration.

3.3 Submission Deadline

PROPOSALS MUST BE RECEIVED BY LORI FUSSELL BY MAY 14, 2001. Proposals may be mailed, faxed, or emailed. (Lori Fussell, 2570 Teton Pines Drive, Wilson, WY 83014, Email: LMFussell@CS.Com, Fax: (307) 739-8958).

3.4 Engineering Proposal Review

A review committee of experts from the automotive industry and research community will evaluate the engineering proposals.

3.5 Engineering Proposal Evaluation Criteria

Proposals will be judged on appropriateness, creativity, quality, durability, and cost-effectiveness of the conversion. Special emphasis will be given to innovative and practical approaches

to reducing noise and emissions. The proposal review form will contain the following categories and point allocation:

Overall Approach	20 points
Preparedness (Project advisor/team/funding/facilities)	20 points
Emission Control	15 points
Noise Reduction	15 points
Power Retention	10 points
Timeline	10 points
Overall Impression	10 points

3.6 Review Committee Decision

Due to limited facilities, only 20 teams will be selected to compete in the SAE CSC2002. However, if in the opinion of the review committee, the number of acceptable proposals is less than 20, a corresponding number of teams will be selected for participation.

The decision of the review committee is final.

3.7 Results Announcement

Engineering proposal review results will be announced by June 1, 2001.

4. SNOWMOBILE MODIFICATION

4.1 Baseline Snowmobile

SAE CSC2002 teams are expected to provide their own snowmobile for modification. The baseline snowmobile must be a stock qualified snowmobile, defined as a model that was produced in a quantity of at least 500 units**.**

The intent of the SAE CSC2002 is for student teams to modify an existing snowmobile to improve emissions and noise characteristics. Teams choosing to ignore this intent by entering a snowmobile made clean and quiet by a manufacturer or aftermarket supplier will be disqualified. Competition organizers will be responsible for making this subjective determination, if necessary.

4.2 Engine

4.2.1 Permitted Modifications

Modifications to the engine, including substitution of a different engine are allowed.

Two-stroke, four-stroke, and rotary engines are allowed. Engine displacement is limited to 600 cc or less for two-stroke and rotary engines, 960 cc or less for four-stroke engines.

4.2.2 Permitted Fuels/Additives

Snowmobiles must be fueled with a blend of 10% ethanol and 90% premium gasoline. Fuel additives (with the exception of commercial two-stroke oil) are not permitted.

4.2.3 Permitted Lubricating Oils

Any type of oil may be used in the modified snowmobiles as long as the oil does not contain any oxygenates or other power boosting additives.

4.2.4 Turbochargers/Superchargers

The use of turbochargers and superchargers is allowed. All superchargers must have a restraint system to prevent them from being blown free of the engine; this includes a flexible blanket shield. Snowmobiles with an unshielded supercharger will not be allowed to compete in the SAE CSC2002.

4.2.5 Exhaust Systems

The exhaust system may be modified, but must meet or beat sound and emission standards detailed in SAE CSC2002 Rules 9.9 and 9.6. The exhaust system emission pipe must not protrude more than three (3) inches beyond the chassis or hood configuration.

4.2.6 Throttle Requirements

An adequate return spring on the throttle is required. The throttle must remain on the right side. The throttle will be operated with a direct mechanical operated thumb

mechanism located on the handlebar to the rear of the machine (no twist grips).

4.3 Drive

4.3.1 Chain Drive Oil Bath Requirement

Solutions that utilize a chain to drive the primary clutch from the engine are permitted. However, this design solution has historically created excessive temperatures and has been prone to failure. Therefore, if this type of drive system is selected, the chain must be enclosed in a case with a constant oil bath.

4.3.2 Transmission

The snowmobile must be propelled with a variable ratio belt transmission.

4.3.3 Brake Performance Requirement

All brake modifications are subject to retaining the braking performance of the original snowmobile. This will be tested during the safety/tech inspection before snowmobiles are allowed to compete in the SAE CSC2002.

The master cylinder, caliper and disc assembly must be commercially available.

If the secondary brake is on the track shaft, the disk may be smaller than 7". Additional brake assemblies may be added. Brake disc on drive axle track shaft must be at least seven (7) inch minimum diameter. Axle shaft may be lengthened to accommodate additional brakes.

Replacement brake disk of aluminum or carbon fiber is not allowed.

4.3.4 Brake Control Handle

The brake control handle must remain in the OEM location (front left side). Brakes must be operative at all times.

4.3.5 Brake Disk Shield

Brake disc must be covered with a shield capable of retaining an accidental explosion.

4.3.6 Disc Contact Area

The disc pad contact surface area may not be reduced more than 15% of the original pad contact surface area.

4.3.7 Clutch Cover

Clutch cover must be separate of the cowl configuration and cover both clutches down to the center of the bolts or below. It must be made of 0.090 inch 6061 T6 aluminum or equivalent and be covered with 6 inch belting. Carbon fiber clutch covers are not permitted. Snowmobiles with removable side panels may bolt clutch cover guard to side panel to meet this requirement.

4.3.8 Moving Parts Isolation

Chains, pulleys, and exposed moving parts will be isolated from the driver and other competitors by shields capable of retaining all accidental explosions and component impacts. No holes may be drilled in protective shields.

Chains that drive the primary clutch from the engine must be enclosed in a case with a constant oil bath per SAE CSC2002 Rule 4.3.1.

4.4 Skis and Ski Suspension

4.4.1 Ski Requirements

Skis must be commercially available.

4.4.2 Ski and Ski Suspension Modification

The snowmobile's skis and ski suspension may be modified. However, the snowmobile must remain ski-steered

4.4.3 Ski Runners

The use of carbide ski runners is not allowed.

4.4.4 Suspension Requirements

Sleds must have a minimum of six (6) inches usable ski suspension. Usable means with rider on sled. Only steel springs are allowed.

4.5 Track, Track Suspension, and Traction

4.5.1 Track and Track Suspension Modification

The snowmobile's track may be replaced with a different track. The track must be a commercially available, one piece, molded rubber snowmobile track. The selected, commercially available track may not be modified. The same track design must be used for all events.

4.5.2 Track Suspension Requirements

Sleds must have a minimum of six (6) inches travel in usable track suspension. Usable means with rider on sled. Only steel springs are allowed.

The snowmobile's track suspension may be replaced and/or modified.

4.5.3 Minimum Track Width

Minimum combined or single-track width is fifteen (15) inches. A 1/8 inch maximum variance in the minimum track width requirement is allowed. No notching or trimming of the track is allowed.

4.5.4 Traction Control Devices

The use of traction control devices such as studs, ice growsers, or paddles is not allowed.

4.5.5 Slide Runner

Slide runners can be drilled. OEM type slide runners may be used as a replacement. Inserts may be added to the slide runner.

Slide rail lubrication systems are not allowed.

4.5.6 Maximum Track Lug Height

The maximum height of track lugs is 2 inches.

4.6 Frame and Body

4.6.1 Rear Snow Flap

A rear snow flap of sufficient material to restrain traction components if thrown from the track will be installed in a permanent manner and shall be held down so as to

contain all mud, snow, rocks, water, etc., at all speeds. The snow flap must overlap from outside of tunnel to outside of tunnel, one (1) inch outside the widest part of the rear tunnel opening. The snow flap must be in contact with the course surface when the rider is on the sled.

4.6.2 Snow Flap: Twin Track

Two (2) separate flaps may be used on twin track sleds.

4.6.3 Snow Flaps: Fastening

The use of springs and/or elastic material for holding down and fastening snow flaps is not acceptable.

4.6.4 Foot Stirrups/Pegs

Foot stirrups/foot pegs constructed of rigid materials may be installed.

4.6.5 Seat

All sleds will be equipped with an upholstered, padded seat with a minimum thickness of one (1) inch, a length of twenty-four (24) inches, and a width of the tunnel.

4.6.6 Body Modification

The snowmobile body may be modified. The hood must have top and side cowling and must contain at least one thousand three hundred (1300) square inches.

4.6.7 Front Bumper Requirement

All snowmobiles must have a front bumper strong enough to support the snowmobile while suspended in mid-air (for ease of lifting).

4.6.8 Decal Space Requirement

Two hundred (200) square inches of space must be left free on the hood/tunnel of the snowmobile for sponsorship decals to be placed upon arrival in Jackson Hole, WY.

4.6.9 Team Number

The team number must appear on both sides of the snowmobile hood. The number must be six (6) inches

high, ¾ inches wide, and be displayed in contrasting colors. The team number must also be displayed in contrasting colors on both sides of tunnel, minimum of four (4) inches high.

4.6.10 Chassis Modification

The snowmobile chassis (bulkhead and tunnel) must be from a stock qualified snowmobile (a snowmobile that was produced in a quantity of at least 500 units). Teams are not permitted to build their own chassis from the ground up. No modifications may be made to the snowmobile chassis that will reduce structural integrity.

4.7 Ignition and Electrical

4.7.1 Safety Disconnect Tether

All machines must be equipped with a safety disconnect tether that is operable at all times. Safety disconnect tethers must be used and attached to the operator whenever the engine is running. The tether must be connected around the operator's wrist (not to his glove or jacket). No alligator clips are allowed. Maximum tether cord length will be five (5) feet. Verification of the tether cord length will be determined at tether cord's fully extended length. The tether switch will be securely mounted in a location on the snowmobile other than on the handlebars.

4.7.2 Battery Fuel Pumps

Battery operated electric fuel pumps must be connected to the tether switch. This includes electrically controlled fuel injection systems.

4.7.3 Battery Box Requirements

Wet cell must be enclosed in a non-conductive battery box. Positive terminal must be shielded. Battery box must be securely held in place.

4.7.4 Head, Tail, and Brake Light Requirement

All snowmobiles are required to have functional head, tail, and brake lights.

4.8 Component Deletion

No changes are allowed that would nullify compliance with federal, state, or provincial safety regulations.

5. RULE QUESTIONS, DISCUSSION, AND COMMUNICATION

5.1 Question Submission

All SAE CSC2002 rule questions must be submitted via the Rule Questions folder in the SAE Clean Snowmobile Challenge Public Discussion Forum on the SAE Website. Questions must include the appropriate SAE CSC2002 Rule #. Organizers will answer questions in the CSC Forum as soon as the Rules Committee agrees upon answers. It is the responsibility of all SAE CSC2002 participants to monitor this forum to keep up to date on competition questions. Answers will not be distributed individually to teams.

(http://forums.sae.org/access/dispatch.cgi/CLEAN_SNOWMOBILE)

5.2 Loopholes and Problems

Any perceived loopholes in or potential problems with the rules should be provided to organizers via the Rules Questions folder in the SAE Clean Snowmobile Challenge Public Discussion Forum on the SAE Website. Suggestions for rule changes must reference the appropriate SAE CSC2002 Rule #, state the current wording of the rule, and contain a suggestion of how the rule should be changed.

(http://forums.sae.org/access/dispatch.cgi/CLEAN_SNOWMOBILE)

5.3 Engineering Ethics

The SAE Clean Snowmobile Challenge 2002 is an engineering design competition that requires performance demonstration of snowmobiles. It is **NOT** a race. Engineering ethics will apply. In all events violation of the intent of the rule will be considered a violation of the rule.

5.4 Participants' Discussion

A Participants' Discussion folder has been provided in the SAE Clean Snowmobile Challenge Public Discussion Forum on the SAE Website. Participants are encouraged to use this folder to ask questions of and share information with other CSC2002 teams.

(http://forums.sae.org/access/dispatch.cgi/CLEAN_SNOWMOBILE)

5.5 Competition Information

Miscellaneous information regarding competition logistics and administration will periodically be posted in the Competition Information folder in the SAE Clean Snowmobile Challenge Public Discussion Forum on the SAE Website and also on the Clean Snowmobile Challenge Website. It is the responsibility of all SAE CSC2002 participants to monitor both the forum and website and have the most recent competition information.

(http://forums.sae.org/access/dispatch.cgi/CLEAN_SNOWMOBILE)
(http://www.sae.org/students/snow.htm)

6. CONDUCT OF THE EVENT

6.1 Safety

The overriding emphasis of the SAE CSC2002 and all its events is on safety. Any unsafe behavior during the SAE CSC2002 will result in disqualification of the student team.

6.1.1 Safety/Technical Inspection

A safety/technical inspection of each snowmobile will be performed after it arrives in Wyoming and before teams are permitted to start the catalyst-aging event. If safety or rule violations are found, the team will be promptly notified. The team must correct all safety issues and rule violations before the snowmobile is permitted to compete in any event.

It is the responsibility of participating teams to arrive at the competition prepared for the inspection. Any delays

in the start of the catalyst-aging event put a team at risk of forfeiting emission testing. Any team that does not complete the catalyst-aging event by 6:00 pm on Sunday, March 24, forfeits their right to an emission test. (See SAE CSC2002 Rule 9.6.1)

Passing the safety/technical inspection does not in any way

imply that SAE, ISEE, the SAE CSC2002, or any individuals acting on their behalf certify that the snowmobile is safe for use. It is the sole responsibility of participating teams to insure that their snowmobiles are safe for entry in the SAE CSC2002.

It is the intent of competition organizers to weigh snowmobiles during the safety/technical inspection. Snowmobiles will be weighed with full fuel. Snowmobile weights will be used for informational purposes only.

6.1.2 Safety Disconnect Tether

Each snowmobile must be equipped with a safety disconnect tether as described in SAE CSC2002 Rule 4.7.1. Twenty-five (25) penalty points will be assessed each time the safety tether is not properly utilized when the engine is on.

6.1.3 Moving Snowmobiles

When snowmobiles are driven anywhere but in practice areas, snowmobile trails, or roadways they must be driven at a walking pace. During the performance events when the excitement is high, it is particularly important that the snowmobile be driven at a very slow pace. The walking rule will be enforced and point penalties will be assessed for violations of this rule.

6.1.4 Support Snowmobiles

Support snowmobiles may be allowed during certain events. The safety equipment listed in SAE CSC2002 Rules 6.2.1 - 6.2.2 must be worn at all times any team member is on *any* snowmobile that is in motion. The same penalties described in SAE CSC2002 6.2.4 will be applied to support snowmobiles.

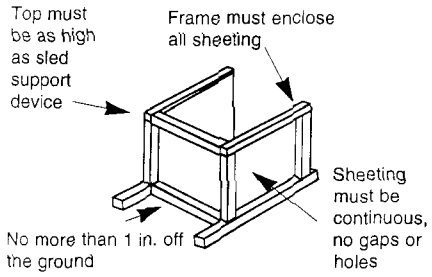
6.1.5 Warm up Stands

Snowmobiles may be warmed up before competing in events. However, this warm-up must take place with the snowmobile mounted in a snowmobile safety stand (you MAY NOT warm up the snowmobile by manually holding the track off of the snow). Twenty-five (25) penalty points will be assessed any time this rule is violated.

The warm-up stand must be designed to catch and retain track, track cleats, traction components and other items that might be thrown by the track. The stand must be no more than six (6) inches from the rear of the tunnel opening and no more than twelve (12) inches from the track. The safety stand will be constructed of metal equivalent to 6061T6 aluminum, 1/8 inch thick. Side panels are mandatory and they must extend at least to the center of the rear axle. The sides and back must be secured inside the framework. Vertical coverage must be no more than one (1) inch off the ice and as high as the snowmobile support device. Coverage must be continuous (no lightening holes). A plywood liner is recommended to help absorb impact. Safety stand must maintain sufficient height to prevent track coming into contact with ground/ice surface. The stand must be used whenever the rear of a machine is raised to clean out the engine or track, and during warm-up.

A sample illustration of a snowmobile warm-up stand is

SNOWMOBILE WARM-UP STAND
sample illustration only (not a design drawing)



provided below (courtesy of the International Snowmobile Racing Association).

6.2 Driver Protective Equipment

6.2.1 Helmet Requirement

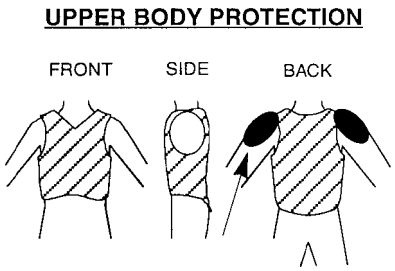
Full coverage helmets (Snell 95 or newer) are mandatory. The helmet must be securely fastened at all times.

6.2.2 Clothing and Boots

Gloves and clothing, along with at least above the ankle boots are mandatory.

6.2.3 Safety Jacket/Vest

A safety jacket/vest that conforms to International Snowmobile Racing guidelines as well as shin and knee guards made of an impenetrable material must be worn by drivers during all competition events. A sample illustration of approved upper body protection is provided below (courtesy of the International Snowmobile Racing Association).



6.2.4 Penalties

Twenty-five (25) penalty points will be assessed for each individual not wearing appropriate safety gear each time the individual is observed to be in violation of the rule by a SAE CSC2002 official. Appropriate safety gear must be worn any time a snowmobile is in motion.

6.3 On Site Modifications Prohibited

No changes or modifications to snowmobiles will be allowed after emission testing except for: 1) those required to fix safety issues, 2) those required to return the snowmobiles to operating condition after a breakdown, 3) or those considered standard maintenance items as described in SAE CSC2002 Rule 6.4

Hoods will be sealed and engine calibrations will be frozen at the beginning of emission testing. Accidental breakage of the seal must be

reported immediately. No telemetry will be allowed. Teams are not allowed to remotely alter calibrations during events. No non-standard user input (other than power, ignition, starter and kill switches) is allowed to the powertrain (includes engine intake, base engine, engine exhaust, or drivetrain).

Twenty-five (25) penalty points will be assessed for each 3-hour period of maintenance required (except for maintenance items listed in SAE CSC2002 Rule 6.4) after emission testing has been completed. *Clarification: Performing 1 sec to 3 hours of maintenance will result in a 25 point deduction. Performing 3 hours and 1 second to 6 hours of maintenance will result in another 25 point deduction.*

In the event that a snowmobile design strategy is "changed" during repairs made after emission testing, the team may continue to compete in SAE CSC2002 events. However, the team will not be eligible to receive any awards for events won after the strategy change.

6.4 Permitted Maintenance Items

The following maintenance items will be allowed throughout the SAE CSC2002 without penalty. Teams must notify and obtain permission from SAE CSC2002 officials before any permitted maintenance items are performed.

- Addition of any fluid – same fluid must be used throughout competition *(NOTE: Adding significant amounts of coolant will not be considered standard maintenance)*
- Suspension adjustment
- Track alignment and tension adjustment
- Drive belt/chain tension adjustment
- Headlight, taillight, brake light replacement
- Tightening of loose bolts: suspension mounting, suspension front limiter strap, ski saddle, and spindle.
- Lubrication of snowmobile parts
- Tightening of rear idler wheel bolts and idler adjusting bolt jam nuts
- Replacement of spark plugs (same plugs must be used as before…2 changes without penalty…then 5 point penalty per plug).

- Replacement of fuel injectors (same injectors must be used as before or design strategy will be considered to be "changed"…2 changes without penalty…then 5 point penalty per injector).
- Oil/fuel filter replacement

NOTE: The intent of this rule is to allow 1000 mile maintenance items to be performed throughout the SAE CSC2002 without penalty. Organizers reserve the right to modify/add to this list as conditions demand.

6.5 Fuel at Competition

Teams are required to power their snowmobile with a blend of 10% ethanol and 90% premium gasoline. Fuel will be provided to all teams throughout the competition. Teams are required to use the provided fuel for all SAE CSC2002 events. Snowmobiles must arrive at the SAE CSC2002 with empty fuel tanks or must be driven to empty before being fueled for emissions testing.

6.6 Lubricating Oil at Competition

Competing teams are responsible for providing their own lubrication oil (two-stroke or four-stroke). Teams will not be allowed to switch the type of lubrication oil they are using once the competition has begun. Doing so without approval from a SAE CSC2002 official will result in disqualification. Oil must be added in the presence of a SAE CSC2002 official and must come from a factory sealed container.

6.7 Drafting Prohibited

Drafting of other snowmobiles will not be allowed during the fuel economy/range event. Drafting is defined as following another vehicle closer than three snowmobile lengths at cruising speeds for sustained periods of time. Infractions of this rule may be reported by other competitors or by SAE CSC2002 officials. Penalties will be loss of points for the fuel economy/range event (25 points per occurrence).

6.8 Unsportsmanlike Conduct

Unsportsmanlike conduct will not be tolerated. Any driver, crew member, faculty advisor, or spectator who by their conduct detracts from the character of the event, or who abuses, threatens, or uses profane language to an official may be assessed a warning or penalty for unsportsmanlike conduct. A second violation may result in

expulsion of the team from the competition. Warnings and penalties may be given by any official and will become record with the approval/concurrence of the organizers.

6.9 Drug and Alcohol Policy

If of legal drinking age, participants, guests, advisors, volunteers, and event staff may drink alcohol during meals and other social activities. However, participants, guests, advisors, volunteers, and event staff are prohibited from drinking alcoholic beverages or being under the influence of alcoholic beverages in any pit area or in any area where snowmobiles are operating or being worked on. There will be a zero-tolerance policy regarding the violation of this rule. Any participant, guest, or advisor violating this rule will cause the immediate disqualification of their team. Volunteers or event staff violating this rule will be dismissed.

There is also a zero-tolerance policy regarding the use of illegal drugs. Any participant, guest, or advisor observed using illegal drugs will cause the immediate disqualification of their team. Volunteers or event staff violating this rule will be dismissed.

6.10 Protests and Problems

Any problems that arise during the competition will be resolved through the organizers and the decision will be final. All protests must be in writing. Protests must be filed within one-hour after scores are posted. The decision of the judges and organizers is final.

6.11 Event Appearance and Forfeits

It is the responsibility of the teams to be in the right place at the right time. If a snowmobile is not ready to compete at the scheduled time, then the team forfeits the run of the event and will not be offered a late make-up. The driver for an event will be disqualified if he/she doesn't attend the driver meeting for the event.

7. SCHEDULE

7.1 Deadlines

7.1.1 *May 14, 2001*

Receipt of student engineering proposals at the address listed in SAE CSC2002 Rule 3.3.

7.1.2 *June 1, 2001*

Participants selected and informed of their selection.

7.1.3 *February 15, 2002*

Team program information is due. Team program information will be submitted via the online Program Information Form on the SAE CSC2002 website at http://www.sae.org/students/snow.htm. A *hardcopy* photograph of the team (Black and White preferred, 4"x 6" or less) must also be mailed to Lori Fussell, 2570 Teton Pines Drive, Wilson, WY 83014 by this date.

7.1.4 *March 15, 2002*

Five (5) hardcopies, one large print (16 point or greater) hardcopy, and two electronic copies (one large print and one standard font, MSWord97 or Adobe Acrobat PDF format) of the typed, final engineering design paper describing the modified snowmobile are due. The reports should be sent to the address listed in SAE CSC2002 Rule 9.4.1.

NOTE: Late engineering design papers will receive 10 penalty points for each day that they are late, up to a maximum penalty equal to the team's score for this event.

7.1.5 *March 15, 2002*

One (1) hardcopy and one (1) electronic copy (MSExcel97 format) of the Technology Implementation Cost Assessment (TICA) are due. A copy of all supporting documentation is also due. The TICA information should be sent to Stephanie Cornelius at the address listed in SAE CSC2002 Rule 9.5.1

NOTE: All teams will be required to update their TICA at the start of the SAE CSC2002 and have their snowmobile inspected to verify that their TICA is complete and accurate. Teams not submitting a complete and accurate TICA will be ineligible to receive the awards for Most Practical Solution and Best Value.

7.2 Event Schedule

7.2.1 March 22, 2002 – Friday

–Optional early arrival at Flagg Ranch: Register, Attend Competition briefing, Complete Safety/Tech Inspection.

7.2.2 March 23, 2002 – Saturday

For teams that arrived on Friday, March 22: Complete 60 mile catalyst-aging ride (8:00 am to 6:00 pm only), TICA Inspection.

ALL TEAMS: Arrive at Flagg Ranch by 5:00 pm, Register, Attend Competition briefing, Complete Safety/Tech Inspection.

NOTE: Teams will receive 25 penalty points for each day that their snowmobile is late. Late snowmobiles also risk loosing the opportunity to have their emissions tested.

7.2.3 March 24, 2002 – Sunday

Teams that arrived early and completed their catalyst-aging event on Saturday: Play in the snow

ALL TEAMS: Complete 60 mile catalyst-aging ride (8:00 am to 6:00 pm only), TICA Inspection.

7.2.4 March 25, 2002 – Monday

Emission Testing

7.2.5 March 26, 2002 – Tuesday

Oral Design Presentations and Any Remaining Emission Testing

7.2.6 March 27, 2002– Wednesday

Fuel Economy/Range Event

7.2.7 March 28, 2002 – Thursday

Acceleration/Noise Event (morning), Handling/Driveability Event (afternoon), Public presentation of selected Oral Presentations (evening)

7.2.8 March 29, 2002 – Friday

Cold Start Event, Hill Climb (morning), Static Display at hill climb (afternoon), Award Ceremony (evening)

7.2.9 March 30, 2002 – Saturday

Snowmobiles remain on static display at hill climb until noon (mandatory).

7.2.10March 31, 2002 - Sunday

Snowmobiles remain on static display at hill climb (not mandatory).

8. AWARDS/PRIZE MONEY

8.1 Prize Money

A total of $21,000 will be available for prizes awarded to the top five places overall in the SAE CSC2002, along with special prizes for winning individual events according to the schedule below. The prize money will be given to the winning schools with the understanding that it will be used for future automotive projects.

First Place Overall	$4,000
Second Place Overall	$3,000
Third Place Overall	$2,000
Fourth Place Overall	$1,000
Fifth Place Overall	$500
Best Performance	$1,500
Best Emissions	$1,500
Best Design	$1,500
Best Fuel Economy	$1,500
Quietest Snowmobile	$1,500
Most Practical Solution	$1,500
Best Value	$1,500

8.2 Award Criteria

Best Performance: Presented to the team receiving the highest total score in the Acceleration, Handling, and Hill Climb Events that also passed both the noise/acceleration and emission event.

Best Emissions: Presented to the team receiving the best score in the emissions event or, in the event of a tie, the best score in the fuel economy/range event.

Best Design: Presented to the team receiving the highest total score in the Engineering Design Paper, Oral Design Presentation, and Static Display Events that has also received passing scores in the emission and noise/acceleration events.

Best Fuel Economy: Presented to the team receiving the most points in the Fuel Economy/Range event.

Quietest Snowmobile: Presented to the team receiving the most noise points in the noise/acceleration event.

Most Practical Solution: Presented to team with the best balance between cost and measured noise and emission reduction. Winner will be the team with the highest (Noise Points + Emission Points)/Technology Implementation Total Cost.

Best Value: Presented to team with the best balance between cost, fuel economy, and performance. Winner will be the team with the highest (Fuel Economy Points + Acceleration Points + Handling Points + Hill Climb Points + Cold Start Points)/Technology Implementation Total Cost.

8.3 Participation Plaque

Each school will receive a plaque commemorating its participation in the SAE CSC2002. Trophies will be given to the winners in each of the categories listed in Section 8.1 of the SAE CSC2002 rules.

8.4 World Championship Hill Climb

In addition to providing points to each school's overall and performance scores, the hill climb event will be a special class of competition in the World Championship Hill Climb up Snow King Mountain. The school receiving the most points in this event that has also passed both the emissions and the noise/acceleration events will hold the world champion title for our class of competition.

9. SCORING

9.1 Overall Score

Overall scores will be determined, based on a maximum of 1500 points, according to the following schedule:

Event	Points for Passing Event	Maximum Additional Points for Relative Performance in Event
Engineering Design Paper	N/A	100
Cost Assessment	N/A	50
Emissions	100	350
Oral Design Presentation	N/A	100
Fuel Economy/Range	100	100
Noise/Acceleration	100	250 (150-noise, 100 accel.)
Handling	N/A	50
Cold Start	75	N/A
Hill Climb	N/A	75
Static Display	N/A	50
All Events	*375 points*	*1125 points*

9.2 Event Points

With the exception of the subjective design events (engineering design paper, oral design presentation, and static display) and the emission event, the team having the best score in each of the events will be awarded the maximum possible points (if they have also passed the event). Teams finishing behind those leaders will be awarded proportionally fewer points according to the scoring schemes that appear at the end of the following items. No negative points other than as a result of penalties will be awarded.

9.3 Penalties

Penalties will result from violating SAE CSC2002 safety rules, performing prohibited maintenance on snowmobiles at any time after

emission testing, drafting during the fuel economy/range event, or failing to meet competition deadlines.

9.4 Engineering Design Paper

9.4.1 Engineering Design Paper Description

This event requires the team to submit an engineering design paper describing the snowmobile conversion concept, design, and implementation. The paper should explain why modifications were performed and the results of testing and development. The paper must address the durability, practicality, and increased cost of any modifications. An absolute limit of **fifteen (15) pages** will be strictly enforced, except as noted below for papers submitted in alternative accessible formats.

FIVE hardcopies of the paper, one hardcopy of the paper printed in 16 point or larger font (not subject to page limit), and two electronic copies of the paper (one large print and one standard) - PDF or MSWord 97 format) are due by March 15, 2002. Late engineering design papers will receive 10 penalty points for each day that they are late, up to a maximum penalty equal to the team's score for this event. Hand written papers will not be accepted. Papers should be sent to: Dr. Lori M Fussell, 2570 Teton Pines Drive, Wilson, WY 83014. **Papers must conform to the standard format for SAE technical papers.** The format for SAE technical papers is available on-line through the SAE website at: www.sae.org/products/papers/paperinfo/prepare.htm.

9.4.2 Engineering Design Paper Scoring

This event is worth a maximum of 100 points. Engineering design paper judges will have a technical background. A sample engineering design paper judging form is located in the SAE CSC2002 Rules Appendix.

9.5 Technology Implementation Cost Assessment

9.5.1 Technology Implementation Cost Assessment Description

Each team is required to submit a Technology Implementation Cost Assessment (TICA) on their modified snowmobile. The TICA's purpose is to provide a standard method to compare the

"manufacturer's cost" (cost TO the end snowmobile manufacturer) of each team's strategy for reducing emissions, noise, and fuel consumption. The TICA is not intended to evaluate the manufacturer's cost of "secondary" modifications such as suspension modifications or more comfortable seats.

It is the organizers' intent to make the completion of the TICA as simple as possible. Each team will be provided with a MSExcel97 spreadsheet that contains three separate worksheets:

1. The first worksheet, the Cost Index Reference, is a read-only worksheet that contains the specific nominal cost for individual components or information on how to determine the cost of individual components. Teams MUST SUBMIT copies of all manufacturer's quotes per 5000, manufacturer specification sheets, and retail receipts that are used to determine the cost of individual components on their snowmobile.
2. The second worksheet, the Cost Subtotals Worksheet, is where teams are required to input specific information on their entry. Only those cells requiring input may be modified. The rest of the spreadsheet is "protected".
3. The third worksheet, The Cost Totals Form, is a read-only worksheet that automatically calculates the final Technology Implementation Total Cost (TITC).

If at any time you have questions about the completion of the TICA spreadsheet, or if it does not adequately "evaluate" a system on your snowmobile, please contact the organizers via the SAE CSC2002 Forum described in SAE CSC2002 Rule 5.1. Organizers are very willing to assist teams with the completion of the TICA and would like it to provide "useful" information

One (1) hardcopy of the TICA, one (1) electronic copy (MSExcel97 format) of the TICA, and a copy of all supporting documentation, are due to Stephanie Cornelius, 3021 Miller Road, Ann Arbor, Michigan 48103, by March 16, 2002.

All teams will be required to update their TICA at the start of the SAE CSC2002 and have their snowmobile inspected by

Stephanie Cornelius to verify that their TICA is complete and accurate

9.5.2 Technology Implementation Cost Assessment Scoring

Fifty (50) points will be awarded to the winner of this event. Other scores will be determined by the following:

$$\text{Your Score} = \frac{\left(\text{TITCyour} / \text{TITCmin}\right)^2 - 1}{\left(\text{TITCmax} / \text{TITCmin}\right)^2 - 1} \times 50$$

TITCs will also be used to determine the winners of the awards for Most Practical Solution and Best Value. Teams not submitting a complete and accurate TICA will be ineligible to receive the awards for Most Practical Solution and Best Value.

9.6 Emissions

9.6.1 Emission Event Description

Before being allowed to undergo SAE CSC2002 emission testing, snowmobiles will pass the safety/tech inspection and complete a catalyst-aging trip (60 miles in length). Teams will have ten hours (8 am to 6 pm) on Sunday, March 24 available in which to complete their catalyst-aging trip. Teams that arrive unprepared or run into problems and are unable to complete the 60 miles before the 6 pm deadline will loose their *right* to emission testing. Emissions of these teams may be tested, after all other teams that met competition deadlines, if and only if time permits. Therefore, we encourage all teams to take advantage of the optional early arrival (See Section 7.2).

In addition to completing the 60 mile catalyst-aging trip, teams must provide the following information to event organizers before being permitted to participate in emission testing: 1) The engine rpm for their snowmobile at idle, 15, 20, 25, 35, and 45 mph; and 2) The snowmobile's maximum steady speed in mph at wide open throttle and the corresponding engine rpm.

Emission testing on each snowmobile will be performed by Dr. Gary Bishop (University of Denver). Carbon Monoxide (CO) and Unburned Hydrocarbon (UHC) emissions will be measured in the field (approximately 6,800 feet above sea level and –10

to 40 degrees Fahrenheit) with an infrared heat beam. Measurements will be taken for two different modes of operation:

1. A gentle acceleration from a standing start to 15 mph (simulating a snowmobile pulling away from an entrance gate).
2. A climb up a gentle hill (3-4 percent grade) at a constant speed of 20 mph.

Ten measurements of each mode will be taken for each snowmobile. The highest and lowest measurements will be thrown out. The remaining eight measurements will be averaged together to generate your snowmobile's UHC and CO emission in parts per million. NOTE: This measurement technique reports UHC concentrations in ppm propane. Standard garage-type analyzers report UHC concentrations in ppm hexane. Two (2) ppm propane equals one (1) ppm hexane.

Detailed information on this emission testing procedure and reference emission values for a typical touring snowmobile are available in the following paper:

Fussell, L.M., Bishop, G., and Daily, J., "The SAE Clean Snowmobile Challenge 2000 – Summary and Results", Society of Automotive Engineers, SAE 2000-01-2552, September 2000.

9.6.2 Emissions Event Scoring

A 2-stroke snowmobile representative of a typical touring snowmobile in the Greater Yellowstone Area will be tested as part of the SAE CSC2002 emission tests. The emission levels measured from this snowmobile will serve as baseline values.

Snowmobiles that have carbon monoxide (CO) emissions greater than 50% of the baseline snowmobile's CO emissions ***or*** unburned hydrocarbon (UHC) emissions greater than 50% of the baseline snowmobile's UHC emissions will fail the event and receive 0 points. Snowmobiles passing the event will receive points according to the following table:

Percent Reduction of CO relative to baseline snowmobile (PRCO)	Points Awarded for CO Reduction	Percent Reduction of UHC relative to baseline snowmobile (PRUHC)	Points Awarded for UHC Reduction
50% <= PRCO <55%	50	50% <= PRUHC <55%	50
55%<= PRCO <60%	68	55%<= PRUHC <60%	68
60%<= PRCO <65%	86	60%<= PRUHC <65%	86
65%<= PRCO <70%	104	65%<= PRUHC <70%	104
70%<= PRCO <75%	122	70%<= PRUHC <75%	122
75%<= PRCO <80%	140	75%<= PRUHC <80%	140
80%<= PRCO <85%	158	80%<= PRUHC <85%	158
85%<= PRCO <90%	176	85%<= PRUHC <90%	176
90%<= PRCO <94%	194	90%<= PRUHC <94%	194
94%<= PRCO <98%	210	94%<= PRUHC <98%	210
98<= PRCO <100%	225	98<= PRUHC <100%	225

Passing teams' final scores in this event will be equal to the points awarded for CO reduction plus the points awarded for UHC reduction.

NOTE: In the event of a tie in this event, the team receiving the most points in the Fuel Economy/Range event will win the award for Best Emissions.

9.7 Oral Design Presentation

9.7.1 Oral Design Presentation Description

A 10 minute oral presentation of the rationale and approach to the conversion is required, followed by a five-minute question and answer period. The presentation should state clearly how your modified snowmobile addresses the needs of snowmobilers (performance), environmentalists/land managers/regulatory agencies (noise and emissions), and snowmobile dealers/outfitters (cost, durability, re-sale value). Your presentation should focus on how your snowmobile will economically and practically reduce the impact that snowmobiles have on the environment. The presentation will be judged on content, format, and delivery. All statements must be backed up with test results and science…this is a marketing delivery that must based in TRUTH.

Each team is required to submit an electronic copy of their oral design presentation to competition organizers at the end of the presentation. Electronic copies may be submitted on 1.4" floppies, a zip disk, or a CD (no email). Teams failing to provide an electronic copy of their oral presentation will receive 0 points for this event. THIS REQUIREMENT WILL BE STRICTLY ENFORCED!

9.7.2 Oral Design Presentation Scoring

This event is worth a maximum of 100 points. Oral design presentation judges will include snowmobilers, environmentalists, land managers, and engineers. A sample oral design presentation judging form is located in the SAE CSC2002 Rules Appendix.

9.8 Fuel Economy/Range Event

9.8.1 Fuel Economy/Range Event Description

All snowmobiles will complete a trip that is approximately 100 miles in length (4, 25 mile legs). Student participants will drive their own snowmobiles in this event. Participants are required to maintain a speed equal to the legal speed limit. The required speed may be lessened for safety in poor driving conditions. The legal speed limit is 45 miles/hour, with 35 miles/hour on some curves. **Team's unable to maintain the set pace will be**

asked to pull over and will be disqualified from the event. Therefore, to pass this event, your snowmobile must be capable of reaching and maintaining a speed of 45mph on high altitude, mountainous, snowmobile trails.

Snowmobiles will leave will full tanks. The amount of fuel required to fill the tank upon return will be used to award points for this event. Drafting is strictly prohibited (see SAE CSC2002 Rule 6.7). Infractions of the drafting rule can be reported by competing teams or by SAE CSC2002 organizers.

9.8.2 Fuel Economy/Range Event Scoring

200 points will be awarded to the winner of this event. Teams that run out of fuel during this event will receive 0 points. Other scores will be determined by the following formula (G = number of gallons of fuel consumed):

$$\text{Your Score} = 100 + \left[\frac{\left(\text{Gmax} / \text{Gyour} \right)^2 - 1}{\left(\text{Gmax} / \text{Gmin} \right)^2 - 1} \times 100 \right]$$

NOTE: The results of this event will be used to determine the winner of the Best Emissions award in the event of a tie in the scoring of the emission event.

9.9 Noise/Acceleration Event

9.9.1 Noise/Acceleration Event Description

Noise measurements of all snowmobiles will be taken according to SAE J192, the SAE recommended practice for measuring the exterior sound level from snowmobiles. This test procedure measures snowmobile noise while under wide open throttle acceleration, with measuring equipment located 50 feet from the road. Tests are performed on both sides of the snowmobile.

Test runs are repeated until three readings within a 2 dBA range per vehicle side have been obtained. The sound level for each side of the snowmobile is recorded as the average of all three readings, rounded to the nearest integer. The sound level used

for scoring purposes will be that for the side of the snowmobile with the highest readings.

The acceleration test will take place at the same time as noise testing. Snowmobiles will be evaluated on the basis of elapsed time to 500 feet from a standing start. Student participants will drive their own snowmobiles in this event. Student participants are **REQUIRED** to operate their snowmobile at wide open throttle during each test. If, in the opinion of the organizers, a team is not operating at wide open throttle, the team will be disqualified from the event. Organizers may randomly assign professional drivers to ride in this event to verify wide open throttle operation.

The acceleration test will be scored based upon the average of three runs for which scored noise data are also obtained (in other words, we will average together the acceleration times that correspond to the noise level measurements of the loudest side of the snowmobile).

All snowmobiles in the SAE CSC2002 are expected to complete this event with a time equal to or less than 10.5 seconds and a sound level equal to or less than 74 dBA. Snowmobiles that do not meet either of these criteria fail the combined event.

9.9.2 Noise/Acceleration Event Scoring

The score for teams that pass both the acceleration and noise tests will determined using the following formula. (Tyour = your average acceleration time, Tmin = the average acceleration time of the fastest snowmobile that passed the noise test, dByour = the average sound level of your loudest side, dBmin = the average sound level of the loudest side of the quietest snowmobile that passed the acceleration test):

$$\text{Your Score} = 100 + \left\{\left[\frac{\left(74/\text{dByour}\right)^2 - 1}{\left(74/\text{dBmin}\right)^2 - 1}\right] \times 150\right\} + \left\{\left[\frac{\left(10.5/\text{Tyour}\right)^2 - 1}{\left(10.5/\text{Tmin}\right)^2 - 1}\right] \times 100\right\}$$

Teams failing either the noise or acceleration test will receive 0 points in this combined event.

9.10 Handling/Driveability Event

9.10.1 Handling/Driveability Event Description

A minimum of five (5) different professional snowmobile drivers will ride snowmobiles around a mini snow cross course. Each driver will evaluate the snowmobile's handling and driveability. This is **NOT** a timed event. Scores will be based upon the drivers' *opinions* only. Sample handling event judging forms are located in the SAE CSC2002 Rules Appendix.

9.10.2 Handling/Driveability Event Scoring

Fifty (50) points will be awarded to the winner of this event. Other scores will be determined by the following formula (H = total of five drivers' scores):

$$\text{Your Score} = \frac{\left(\text{Hyour}/\text{Hmin}\right)^2 - 1}{\left(\text{Hmax}/\text{Hmin}\right)^2 - 1} \times 50$$

9.11 Cold Start Event

9.11.1 Cold Start Event Description

Snowmobiles will be cold-soaked overnight. Teams will have exactly twenty seconds to start their snowmobile. The use of ether is not allowed.

9.11.2 Cold Start Event Scoring

Snowmobiles that do not start within 20 seconds will fail the cold start event and will receive 0 points. Snowmobiles that start within 20 seconds will receive 75 points.

9.12 Hill Climb

9.12.1 Hill Climb Description

The hill climb event will be scored based on maximum height reached and/or elapsed time to climb a course up Snow King Mountain. The course is approximately 3000 feet long, has an average grade of 19 degrees (39%), and a maximum grade of 30 degrees (60%). Snowmobiles will be driven by professional snowmobile drivers, assigned randomly.

9.12.2 Hill Climb Scoring

Snowmobiles that do not reach the top of the course will be scored according to the following formula (Dyour = your highest distance on the hill, Dmax = highest distance by any snowmobile on the hill)

$$\text{Your Score} = \left(\text{Dyour}/\text{Dmax}\right)^2 \times 50$$

Snowmobiles that reach the top of the course will be scored according to the following formula, with the winner of this event receiving 75 points. (Tyour = your time, Tmax = longest time of the snowmobiles that succeed in climbing the hill, Tmin = shortest time of the snowmobiles that succeed in climbing the hill.)

$$\text{Your Score} = 50 + \left[\left(\frac{\left(\text{Tmax}/\text{Tyour}\right)^2 - 1}{\left(\text{Tmax}/\text{Tmin}\right)^2 - 1} \right) \times 25 \right]$$

9.13 Static Display

9.13.1 Static Display Description

Each school will place their snowmobile on display at the World Championship Hill Climb. An outdoor, tented area will be provided for your snowmobile and display. The display is intended to serve as a marketing/promotional display that will encourage snowmobilers and outfitters to use/purchase your snowmobile. Teams are encouraged to put up signs, hand out flyers, and use any other marketing techniques to attract attention to your prototype snowmobile. This is a judged event, with judging taking place on Friday afternoon. 3:00 pm. Teams are encouraged to display their snowmobile through the end of the Hill Climb on Sunday afternoon.

9.13.2 Static Display Scoring

This event is worth a maximum of 50 points. Static display judges will have a technical background, be active snowmobilers, and/or be concerned about the impact of snowmobiles on the environment. A sample static display judging form is located in the SAE CSC2002 Rules Appendix.

10. ORGANIZER AUTHORITY

The organizers of the competition reserve the exclusive right to revise the schedule of the competition and/or to interpret the competition rules at any time and in any manner which is, in their sole judgment, required for efficient operation or safety of the competition.

SAE CSC2002 Engineering Design Paper Judging Form

Score the following categories, giving each points ranging from 0 (very bad) to the maximum points available for the category (excellent). The maximum points available for each category are listed in parenthesis.

When evaluating the papers, please keep in mind that the papers should be high-quality, technical papers that meet the rigorous standards required for publication in scholarly journals.

_____ **CONTENT – PERFORMANCE (15):** Does the paper describe the challenges of maintaining/improving snowmobile performance (while reducing emissions and noise)? Does the paper describe the strategy the team selected to maintain/improve performance? Are adequate technical details given? Are adequate results given?

_____ **CONTENT – EMISSION CONTROL (15):** Does the paper describe the challenges of improving snowmobile emissions? Does the paper describe the strategy team selected to improve emissions? Are adequate technical details given? Are adequate results given?

_____ **CONTENT – NOISE (15):** Does the paper describe the challenges of reducing snowmobile noise? Does the paper describe the strategy team selected to reduce noise? Are adequate technical details given? Are adequate results given?

_____ **CONTENT – MISCELLANEOUS (10)** Does the paper describe other features of the snowmobile? How will the modifications effect the cost of the snowmobile? Will the snowmobile be durable? Will the snowmobile be energy efficient? Will the snowmobile be comfortable and safe to ride?

_____ **RESULTS/DATA – (15)** Does the paper contain valid numerical data? Are results described based upon testing?

_____ **ORGANIZATION (10)** Was the paper format logical and organized? Did it contain an introduction/overview as well as conclusion/summary? Did the paper conform to the SAE standard format for technical papers?

_____ **USE OF GRAPHICS – TABLES/GRAPHS/PICTURES (10) -** Were graphics used in the paper? Were they clearly explained in the text? Were they legible? Were they effective?

_____ **REFERENCES (10)** Were references cited whenever appropriate? Were the references from high-quality sources?

_____ **TOTAL = ENGINEERING DESIGN PAPER POINTS (100 Points maximum)**

COMMENTS: _____

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SAE CSC2002 Oral Presentation Judging Form

Score the following categories on the basis of 0-12.5 points each according to the following scale (any number or fraction along this scale may be used).

0	=	inadequate or no attempt
2.5	=	attempted but below expectation
5	=	average or expected
7.5	=	above average but still lacking
10	=	excellent, meets intent
12.5	=	extraordinary, far exceeds expectations

_____ **CONTENT (SNOWMOBILE OPERATOR PERSPECTIVE):** Does the presentation describe how the design will appeal to snowmobilers? Will the snowmobile maintain/improve performance and handling? Is enough detail given about how? Are there other factors that make this design more attractive to snowmobile operators?

_____ **CONTENT (SNOWMOBILE DEALER/OUTFITTER PERSPECTIVE):** Does the presentation describe how the design will meet the needs of snowmobile outfitters? Is the cost reasonable? Is the design durable and easy to maintain? Does the design allow operation by a novice snowmobiler? Is enough detail given about how these goals are met? Are there other factors that make this design more attractive to snowmobile dealers/outfitters?

_____ **CONTENT (ENVIRONMENTAL PERSPECTIVE):** Does the presentation describe how the design will minimize the environmental impacts of the snowmobile? Are emissions reduced significantly? How much? Is the snowmobile quiet enough? How quiet? Is enough detail given about how these goals are met? Are there other factors that make this design more attractive from an environmental perspective?

_____ **CONTENT (TEST RESULTS/SCIENCE):** Are test results given for all of the "claims" made about the modified snowmobile? Is the presentation based on "good science" (as opposed to a slick sales job)? Is data provided to support all conclusions?

_____ **ORGANIZATION:** Were the concepts presented in a logical order progressing from basic concept and showing how the engineering accomplished the concept? Was it clear to the audience what was to be presented and what was coming next? Were distinct introduction and overviews as well as summary and conclusions given?

_____ **VISUAL AIDS:** Were visual aids used? Was the text readable? Were illustrations, graphs, and tables clearly explained? Were the visual aids effective?

_____ **DELIVERY:** Did the presenter speak in a clear voice? Did the presenter show enthusiasm and promote confidence in the technical aspects? Did he/she maintain eye contact?

_____ **QUESTIONS:** Did the answer illustrate that the team fully understood the question? Is there doubt that the team understood the answer? Did the team promote complete confidence in their response to the questions?

_____ **TOTAL = PRESENTATION POINTS (100 Points maximum)**

COMMENTS: _____

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SAE CSC2002 Static Display Judging Form

Score the following categories on the basis of 0-12.5 points each according to the following scale (any number or fraction along this scale may be used).

0	=	inadequate or no attempt
2.5	=	attempted but below expectation
5	=	average or expected
7.5	=	above average but still lacking
10	=	excellent, meets intent
12.5	=	extraordinary, far exceeds expectations

When evaluating the snowmobile and its static display, please keep in mind that the intent of this event is to encourage the student designs to be appealing to snowmobilers and snowmobile tour operators.

_____ **AESTHETICS:** Does the snowmobile look attractive? Does it have a high performance appearance? Does have a quality appearance? Does it look fun to ride?

_____ **STUDENTS:** Were the students present? Were they outgoing? Did they offer to tell you about their snowmobile? Did they seem knowledgeable? Were they able to answer your questions?

_____ **DISPLAY/INFORMATION:** Are marketing-type materials provided (pamphlets, standing posters, etc.)? Are they informative? Would you be able to learn anything about the snowmobile if there weren't any students around?

_____ **OVERALL IMPRESSION:** Were you convinced that the snowmobile would have enough power to be fun to ride on groomed trails? Were you convinced that a tour operator could use a fleet of these snowmobiles and still make money? Do you think this snowmobile is environmentally friendly? Would you buy one?

_____ **TOTAL = STATIC DISPLAY POINTS (50 Points maximum)**

COMMENTS: _____

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SAE CSC2002 Handling Event Judging Form

Score the following categories, giving each points ranging from 0 (very bad) to the maximum points available for the category (excellent). The maximum points available for each category are listed in parenthesis.

_____ **CORNERING (5 points maximum):** Does the sled have solid steering? Is handling responsive? Do you have confidence that the sled will go where you point it?

_____ **RIDE (5 points maximum):** Does the sled impress you as rideable? Could you ride this sled all day and be comfortable? Is sled ride consistent and smooth?

_____ **ENGINE RESPONSE (7.5 points maximum):** Is the engine response quick and sure? Do RPM's increase/decrease quickly and smoothly? Is there any hesitation to increase RPM?

_____ **CLUTCH/TRACTION (7.5 points maximum):** Does the clutch engage smoothly? Does the drive train put power to the snow well?

_____ **BRAKING (7.5 points maximum):** Do the brakes engage properly? Are you confident the brakes will perform in an emergency situation?

_____ **BALANCE (7.5 points maximum):** Is the sled balanced front to back and side to side? Is the sled nose heavy? Does is torque to the side?

_____ **OVERALL PERFORMANCE (10 points maximum):** Do all parts of the performance seem to fit together? Are the controls simple and easy to operate? Are the handlebars, seat, and footrest comfortable and well laid out?

_____ **TOTAL HANDLING EVENT POINTS (50 Points Maximum)**

COMMENTS: _____

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